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IEEE Std 3001.4™-2020

Recommended Practice for Estimating the Costs of Industrial and Commercial Power Systems

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IEEE Std 3001.4™-2020

IEEE Recommended Practice for Estimating the Costs of Industrial and Commercial Power Systems

Sponsor

Industrial and Commercial Power Systems Standards Development Committee
of the
IEEE Industry Applications Society

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IEEE SA Standards Board

Abstract: Described in this recommended practice are methods for estimating the costs of industrial and commercial power systems, both new and those undergoing expansion or modernization. This recommended practice is restricted to the development of the relative capital cost of industrial and commercial power distribution systems. While this document briefly points out considerations related to total cost or true cost, as well as some technical considerations, other standards and references should be referred to for a thorough analysis of these aspects of power distribution systems. This recommended practice is likely to be of greatest value to the power-oriented engineer with limited experience in this area. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems.

Keywords: costs, cost estimating, estimating, IEEE 3001.4, industrial and commercial power systems, net present value, relative capital cost

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Introduction

This introduction is not part of IEEE Std 3001.4–2020, IEEE Recommended Practice for Estimating the Costs of Industrial and Commercial Power Systems.

IEEE 3000 Series®

This recommended practice was developed by the Industrial and Commercial Power Systems Standards Development Committee of the IEEE Industry Applications Society as part of a project to repackage IEEE's popular series of "color books." The goal of this project is to speed up the revision process, eliminate duplicate material, and facilitate use of modern publishing and distribution technologies.

When this project is completed, the technical material included in the 13 "color books" will be included in a series of new standards. Approximately 60 additional "dot" standards, organized into the following categories, will provide in-depth treatment of many of the topics formerly covered in the color books:

— Power Systems Design (3001 series)
— Power Systems Analysis (3002 series)
— Power Systems Grounding (3003 series)
— Protection and Coordination (3004 series)
— Emergency, Stand-By Power, and Energy Management Systems (3005 series)
— Power Systems Reliability (3006 series)
— Power Systems Maintenance, Operations, and Safety (3007 series)

In many cases, the material in a "dot" standard comes from a particular chapter of a particular color book. In other cases, material from several color books has been combined into a new "dot" standard.

The material in this recommended practice largely comes from IEEE Std 141™-1993, IEEE Recommended Practice for Electric Power Distribution in Industrial Plants, (*IEEE Red Book*™).

IEEE Std 3001.4™

This publication provides a recommended practice for the electrical design of commercial and industrial facilities. It is likely to be of greatest value to the power-oriented engineer with limited commercial or industrial plant experience. It can also be an aid to all engineers responsible for the electrical design of commercial and industrial facilities. However, it is not intended as a replacement for the many excellent engineering texts and handbooks commonly in use, nor is it detailed enough to be a design manual. It should be considered a guide and general reference on electrical design for commercial and industrial facilities.

Tables, charts, and other information that have been extracted from codes, standards, and other technical literature are included in this publication. Their inclusion is for illustrative purposes; where technical accuracy is important, the latest version of the referenced document should be consulted to assure use of complete, up-to-date, and accurate information.

Contents

IEEE Recommended Practice for Estimating the Costs of Industrial and Commercial Power Systems

1. Scope

This recommended practice describes how to estimate the costs of industrial and commercial power systems, both new and those undergoing expansion or modernization. This recommended practice is restricted to the development of the relative capital cost of industrial and commercial power distribution systems. While this document briefly points out considerations related to total cost or true cost, as well as some technical considerations, other standards and references should be referred to for a thorough analysis of these aspects of power distribution systems. This recommended practice is likely to be of greatest value to the power-oriented engineer with limited experience in this area. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

AACE 18R, Cost Estimate Classification System—As Applied in Engineering, Procurement, and Construction for the Process Industries, AACE International.[1]

3. Definitions, abbreviations, and acronyms

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[2] Regarding terms used for finance and investment, e.g., *rate of return, cost of money, internal rate of return, payback rate*, *return on investment*, etc., refer to definitions by the Downes and Goodman dictionary [B3].[3]

detailed estimate: The definitive amount of individual components, resources, and duration to execute the project.

[1]AACE International publications are available online at https://web.aacei.org/.
[2]*IEEE Standards Dictionary Online* is available at: http://dictionary.ieee.org.
[3]The numbers in brackets correspond to those of the bibliography in Annex C.

NOTE—This is most accurate with final project documents.[4]

model estimate: The mathematical, computational algorithms, and parametric equations used to estimate the cost for a product or a project.

parametric detailed estimate: An estimate that uses a unit cost or rate for each specific type of material or activity, and multiplies by the quantity or duration required for the project or activity.

project comparison estimate: A historical cost associated with past results applied to a scalable model for the same or similar type of task or project.

unit-based estimate: The comprised elements of labor, components, and activity to establish the cost basis of an indivisible entity.

NOTE—This establishes the standard unit of accommodation multiplied by cost per unit. The estimate is prepared by multiplying the number of accommodation with the cost per unit of accommodation.

3.2 Abbreviations and acronyms

IRR	internal rate of return
MEP	mechanical/electrical/plumbing
NPV	net present value
VFD	variable frequency drive
WBS	work breakdown structure

4. Estimating, a critical process to project success

4.1 Introduction

An important stage in planning to meet a plant's power requirements is the preparation of a cost estimate. A cost estimate is required for determination of necessary funding, and to help decide if the project is economically feasible. Proper estimates also entail an economic comparison of alternate system arrangements to meet the plant power requirements for the most economical investment in the electrical system. Cost estimating should be part of system design from the preliminary stage through final design, since cost-effective design improvements are made most easily at these stages. Failing this, any such design enhancements, if made at the construction stage, are at greater cost and with less latitude. This recommended practice presents a method for making a capital cost estimate for a typical plant power distribution system.

System cost, while important, is one of several factors to be considered in planning the most suitable distribution system. Consideration should be given to the concept of total cost, or true cost. This requires weighing the first cost of the equipment plus other costs for improved reliability, ease of maintenance, safety, replacement parts, and performance. Useful information concerning cost versus reliability analysis can be found in IEEE Std 493™-2007 [B4]. Additional factors, such as tax considerations, utility rates, operational economies, and provision for future improvements in the manufacturing process, are critical in the evaluation of competing systems. For a given installation, the engineer should prepare alternate power distribution schemes that can be reviewed with the company's financial planning group to develop true cost.

[4] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

This recommended practice, though restricted to the development of the relative capital cost of power distribution systems, can serve as a guide to development of actual cost of installations, thereby providing vital information for budgeting, funding, and evaluation of proposals and bids. While this document briefly points out some technical considerations, other publications, as listed in Annex B and Annex C, should be referred to for a thorough analysis of the technical aspects of power distribution systems.

The fundamental information in this recommended practice is applicable globally that the user exercises discretion when adapting it to local conditions. The fundamentals apply to every application; however, it is incumbent upon the user to employ the guidelines in a manner that recognizes local conditions.

The cost estimate will be prepared for a specific entity or entities with a focus on the viewpoints and requirements of the recipients. For example, an owner may place prime importance on reliability and operating cost; a lessor may be more interested in initial capital cost; a contractor may look at profit margin; a governmental agency may have different requirements altogether; an engineer might favor an elegant design that is state of the art. Address these viewpoints directly at the start of the initial design, with options and cost for the several requirements clearly presented. The entities who use the cost estimate then can compare and evaluate the options and can resolve conflicting viewpoints.

After the basic cost estimate is completed, the economic value of the project for the specific entity will be determined using a variety of approaches. Various owners, lessors, contractors, and others use many different approaches. Consult with the ultimate decision maker to determine the governing basis for economic judgment. A partial list of evaluation methods are shown below. The broad field of evaluating economic value is beyond the scope of this document.

Estimates can be classified by their attributes as follows:

a) Detailed estimate
b) Unit-based estimate
c) Model-based estimate
d) Parametric detailed estimate
e) Project comparison

Detailed estimates: Preparation of a detailed estimate consists of detailing the commodity quantity, length, size, tasks etc., to achieve the drawing and specification requirements. Then a determination of the cost of each item is documented. This level of detailed quantification is extracted from a final set of engineered drawing plans that can enable accuracy in developing the estimate. Construction equipment, tools, and labor resources are developed pertaining to the activities of the project that can include demolition, excavation, followed by construction and installation of equipment and materials according to the plans. The time associated for the activities is typically assembled in a work breakdown format that is established in a construction schedule. The work is sequenced by discipline in single and parallel activities and involves inspection hold points, milestones, and substantial completion dates. A detailed estimate is a definitive cost estimate and regarded for the thorough detail of all areas of work. It is in contrast to a conceptual estimate, although the process can begin with a conceptual and progress as the details are solidified by the engineer on the final drawings and specifications, and can become very detailed.

Unit-based estimate: Unit-based estimating is consolidating the required elements and associated costs for a standardized unit of accommodation. The standard unit of accommodation is multiplied by the cost per unit to equate a unit estimate. The unit-based estimate is useful for design estimates or bidding of projects where unit costs can comprise the overall project. The methods can be considered unit quantity or total quantity:

a) ***Unit quantity*** estimating divides the work into the number of activities/tasks and the number of items. The unit of measurement is selected and the cost per unit quantity of each is derived. The item cost can be calculated by multiplying the cost per unit quantity by the number of units. This is a way to quantify the total cost which includes the material, labor, plant, overhead and profit costs. This method allows comparison to other projects with variations in quantities.

b) ***Total quantity*** method has subdivisions for:

1) Materials
2) Labor
3) Plant
4) Overhead
5) Profit

Each of the subdivisions are costed out per the work and then summed to the total estimated cost of each item of work. An example for a panelboard installation within a new building is shown in Table 1.

Table 1—Example of a total quantity estimate

Item no.	Component	Cost
1	(i) Cost of materials at the source	$
	Breakers and fixed lock hasps	$
	Enclosure with dead front and swinging panel door	$
	Bus. insulators and mounting hardware	$
	Equipment ID, Panel schedule and arc-flash labels	$
	(ii) Cost of handling, shipping, assembly, and delivery	$
2	Cost of labor (skilled and unskilled)	$
3	Cost of plant (tools, e.g., torque wrench, ladder, etc.)	$
4	Overhead (typical = % x (#1+#2+#3))	$
5	Profit (typical = % × #4)	$
	Total cost of panelboard installed (= #1+#2+#3+#4+#5)	$
NOTE—Cost values are for illustrative purposes only and should not be applied to any actual estimates.		

Model estimate: The model method has both direct and variable costs that function with the input of parameters, including resource requirements. The amount of resources that contribute to the project or product have impact to the model outputs in cost and time. The accuracy of the inputs to model formulas can provide estimates with variables in resources and fixed costs with ranges when quantity, conditions, scaling, etc., are factored in. The model can be used to obtain approvals from management and incorporated into business plans for purposes of budgets, financial plans and tracking costs. Modeling for estimates has additional features that show in 2D-3D where locations, size of space requirements, interference with other utilities and equipment that can cause unforeseen conditions. As the model progresses in maturity, so can the estimate. Software that supports this approach have grids for estimating lengths, routing, and sizing for a more effective takeoff on materials. This approach provides sharing of details through a visualization of the proposed product with enhancements through color rendering and views/directions. The model can support construction phase, including turnover, to the client upon completion.

Parametric detailed estimate: The parametric estimate uses the unit-based cost and quantity of units to install or construct for the project. The level of accuracy is improved since the factors are in the unit-base costs and then duration is estimated on multiples of the base cost. This method involves the relationship between

variables to calculate the cost or time. The parameters or conditions that foster the development are analyzing past events and trends. The formulas, equations, or mathematical relationships applied are based on experience per project performance (cost, resources) characteristics utilizing a range of historical projects to provide cost proposals where risk analyses were executed to manage the work efficiently and overcome barriers effectively. The parametric method incorporates lessons learned, best practices, and economic analysis data related to technical, programmatic, cost, and resource characteristics consumed to provide the end item.

Project comparison: Comparison estimating requires some similar, historical projects to make an analogy to the present. The accuracy of this method can increase where the same project management is used and the projects past and present are very similar. This can also be realized with experienced craft/construction crews and subcontractors where past involvement create efficiencies in activities, material and equipment orders, and safety. Comparison of past projects, including simple paybacks or internal rates of return, may be more meaningful to the management tasked with approval, but also for expedited decisions without knowing the details. This approach is relying on expert judgment with an understanding of resource availability, economic trends, and the risks involved.

4.2 Cost estimating users and uses

Financing. Financial sources need to know precisely how much money is required, and when it is needed. Financing may come from financial reserves, capital investments, grants, borrowing, or from other sources. If the estimate is low, there may not be enough money available to complete the job properly; if the estimate is high, the project may be cancelled, or the cost of financing becomes higher than it should be or competing projects may be shelved. For a project that will extend over a long period or that will start at some time in the future, projecting the need for money versus time can be a consideration. Delayed expenditures may involve factors such as estimating inflation rates, forecasting prospective value of the currency used, and other considerations that should be resolved with the financial experts on the project. Financial managers want to rest assured that they obtain the right amount of funding for the project, not too much and not too little.

Project budgeting. The cost estimate tells how much money will be needed to complete the scope of the project. After the budget is approved, the budget restricts how much money can be spent to complete the job. A common tendency is to estimate on the high side so the project will not run out of money before it is finished, however, this tendency should be avoided because an estimate that is too high may cause a good project to be rejected, or the cost of financing may be excessive, or other projects may be shelved. Hence the importance of a realistic estimate.

Bidding. Bidding typically means competitive bidding, with the lowest bid usually winning the contract. That leads to the realization that the bid estimate should include all actual costs so the bidder does not lose money and remain below other bidders or the contract will be lost. Bidders characteristically have their own confidential refinements for preparing a bid. A correct estimate is crucial. The National Electrical Contractors Association (NECA), for example, offers its members extensive information and training about estimating.

Construction. Economic constraints require that the total work of the project shall be accomplished within the limits of the budget. Construction managers use the budget together with the cost estimate to track and manage progress throughout the construction period. The cost estimate should be structured in such a way that it accommodates use of the cost breakdowns for construction management. Consider engaging the help of the prospective construction manager to be certain that all relevant factors have been taken into account.

Contracts, litigation, ethics. Cost estimates lead to contracts involving money (and other things). Money problems or conflicts can lead to litigation. The estimating engineer must meet ethical standards throughout the entire process. The problem is not so much the question of estimating but the question of how to deal ethically with other people, governmental agencies and with corporate entities. Remember who engaged you; support his interests honestly. Maintain confidentiality, even if it is not spelled out explicitly. Maintain your professional position as an engineer. At all times, ensure that all understandings, agreements and negotiations are recorded in writing and when possible signed or documented in such a manner that it is clear what all

parties agreed to. Understand your responsibilities by becoming familiar with IEEE guidelines on Ethics and Member Conduct [B4] and National Society of Professional Engineer (NSPE) Code of Ethics for Engineers [B17]. Also be aware of ethical requirements of the licensing entities in the applicable jurisdictions (i.e., State Board of Engineers, Canadian provincial engineering licensing bodies).

Risk analysis. The risk associated with an event is a function of the probability of the event and the consequences of the event. A convenient way to calculate risk, especially when the consequences can be expressed in monetary terms, is to multiply probability by consequence.

The calculation of risk is a joint responsibility of the engineer and the client. The engineer is generally adept at using mathematics and should take the lead in the determining the probabilities of events; the client is generally very familiar with the financial consequences of things that go wrong. Working together, engineer and client should identify which possible events are to be considered and then proceed with the calculations.

The mathematics of probability is covered in IEEE Std 3006.5™ [B6]. Tools for applying probability, such as Reliability Block Diagrams, Fault Tree Analysis, and Failure Modes, Effects, and Criticality Analysis (FMECA), are discussed in IEEE Std 3006.7™ [B7]. There are many textbooks on the subject of risk. An especially useful one is by Kumamoto, Hiromitsu and Henley [B12].

Approvals. Find out which approvals, inspections, authorizations, and similar requirements apply. Check to see if similar requirements for other disciplines will affect your project. Allow for the cost of these items.

Information for future projects. Keep a permanent copy of the estimate for reference for future projects. If possible, include a copy of actual costs for comparison, with the objective of becoming more accurate and faster when preparing another estimate.

4.3 Capital costs (company practices, accounting practices)

The compilation of an estimate's units are normally expressed in a form of currency based on the project locale, e.g., within the same state, continent, or global. Inherent with cost estimates are economic cycles, monetary, and company policy or financial requirements. The company policies are more familiar as Terms and Conditions that manifest within the accounting processes for establishing fiscal year budgets, expenditures and capital projects as well the practice of closing the books with annual accruals. Industrial as well commercial projects conducted in combination with private, public works, or government/federal agencies in the United States of America can be subject to wage rate and hour determination, as well state and or local bargained wage/hour determination including where subject to burdens. [B18]

4.4 Commissioning and training costs

There are costs for the quality assurance and quality control to assure the owner's project requirements specific to performance are met and the transition to operations and maintenance to ensure the full life cycle of the of the project deliverable. The term commissioning involves costs associated with equipment 3rd part test services, manufacturer's representatives, Mechanical Electrical Plumbing (MEP) coordinator(s), commissioning authority, test equipment, focused to change from the static state to the dynamic state for a fully functional and operational system. This starts at the component instrumentation calibration and controls point to point checks followed by equipment and then system functional tests. Commissioning can be extended to optimize under full seasonal conditions with trending referred to as enhanced commissioning. Commissioning of different systems, e.g., fire detection and notification, substations, standby/emergency generators, etc. may have prescriptive requirements per associated code and standard(s); ASHRAE, NFPA, IEEE. (ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers).

The transition to operations and maintenance includes receipt of Operations and Maintenance Manuals (O&Ms) after equipment purchases to support commissioning and training content. Training per an agenda

may include classroom, site visit and demonstration and may require video recording of each. Training should include the various modes of operation; normal, emergency, standby and maintenance. Operations and maintenance personnel typically attend the training and can be tailored to enhance knowledge for successful project transition.

4.5 Operating costs, installed cost plus variables, inflation

Indirect and direct cost sources provide for the foundation of construction and management up through the commissioning and transfer of operation with turnover document phase(s). The installed costs may be spread over several months/years and have exposure to inflation of labor, material, and equipment costs. Raw material production can also be a variable to the final product pending manufacturing and commodity cost inflation. The transition to beneficial occupancy or final acceptance concludes with the initial installed costs to operation and begins the useful service and return on investment.

4.6 Total cost (return on investment, net present value, operating life)

Totaling the full estimated costs of indirect, direct and associated influential variables per the sources provide for a final sum and or range with percent accuracy applied. This may be accompanied with assumptions and excluded costs to maintain a realistic cost for execution. The delivery will be linked with a project schedule combined with a construction schedule that could be cost and resource loaded per the work break structure. Following this method of determining costs allows the financial analysis to conduct the rate of return, return on investment, and at what cost of money over the project and operating life; life cycle costs. The net present value (NPV) or worth consists of cash flow spread over several to many years. (For definitions of such terms as *time value*, *discount*, *discount yield*, *compound interest*, *efficient market*, *market value* and *opportunity cost,* refer to Downes and Goodman, [B3].)

An earned value management approach provides milestone payment structures to be developed and tracked to activity accomplishments, substantial completion and beginning of production or placement into operation. The costs associated of money due to inflation, escalation and operational costs, cost of borrowed monies with incremental interest tied to the number of years will establish the level of funding overall and annually. The cost of money can be developed with a simple payback, compounded with multiple year paybacks. Paybacks can be augmented with offsets for production, and maintenance and sustainability costs.

Once each cash inflow/outflow is discounted back to its present value (PV) (1), then all are summed together (2). Therefore, NPV is the sum of all terms as shown in Equation (1):

$$\mathrm{PV} = R_t / (1+i)^t \tag{1}$$

where

t time of the cash flow
i discount rate, i.e., the return that could be earned per unit of time on an investment with similar risk
R_t net cash flow i.e., cash inflow minus cash outflow, at time t. For educational purposes initial investment R_0 is commonly placed to the left of the sum to emphasize its role as (minus) the investment

The result of (1) is multiplied with the annual net cash inflow and reduced by initial cash outlay. In cases where the cash flows are not equal in amount, then the previous formula will be used to determine the present value of each cash flow separately. Any cash flow within 12 mo will not be discounted for NPV purposes; nevertheless, the usual initial investments during the first year R_0 are summed up as negative cash flow (see Khan, [B11]).

Given the (period, cash flow) pairs (t , R_t) where N is the total number of periods, the net present value NPV is given by Equation (2):

$$NPV(i,N)=\sum_{t=0}^{N}\frac{R_t}{(1+i)^t} \tag{2}$$

NPV calculations are useful for demonstrating the worth of investments or for the benefits of projects that are expected to create energy savings over time.

Investment Analysis example: A $5000 initial investment is expended (cash outlay; negative for cash outflow). During the next four years three yearly payments of $125 each are received followed by a $5500 final payment at year four (positive for cash inflow). A performance criterion of at least 5% interest is assumed. Verify the investment is an opportunity where the return out performs the risk:

Calculation steps are as follows:

Initial PV = $-\$5,000$

Year 1 PV = $\$125/(1+0.05)^1 = \$119.05$

Year 2 PV = $\$125/(1+0.05)^2 = \$113.38$

Year 3 PV = $\$125/(1+0.05)^3 = \$107.98$

Year 4 (final Payment) PV = $\$5,500/(1+0.05)^4 = \$4524.86$

$NPV = -\$5000 + \$119.05 + \$113.38 + \$107.98 + \$4524.86 = -\$134.73$. The NPV is negative, which indicates that the risk is higher than the performance criteria and is not an acceptable investment opportunity. It may be acceptable using a lower level risk, i.e., a lower interest rate:

Recalculate using 4%: interest rate is as follows:

Initial PV = $-\$5,000$

Year 1 PV = $\$125/(1+0.04)^1 = \$120.19$

Year 2 PV = $\$125/(1+0.04)^2 = \$115.57$

Year 3 PV = $\$125/(1+0.04)^3 = \$111.12$

Year 4 (final Payment): $PV = \$5,500/(1+0.04)^4 = \$4701.14$

$NPV = -\$5000 + \$120.19 + \$115.57 + \$111.12 + \$4701.14 = \$48.02$. The NPV is a positive number that indicates the investment opportunity may be acceptable.

An interest rate that makes the NPV zero, is called the Internal Rate of Return (IRR). The IRR should be higher than the cost of funds.

Energy Project Example: Energy savings are realized through electrical upgrades such as integrating a variable frequency drive (VFD) into an existing constant speed motor application running utilization loads such as pumps, fans, etc., to reduce power consumption:

Example: The VFD costs $5000 and is installed during a scheduled outage. The assumed payback rate in energy is $0.11 per kWh, considering 24 h per day, 365 d per year at 30% energy savings—assume 100 kW (100 hp) and results in 876 000 kWh per year. The 30% savings reduces normal annual energy consumption to 613 200 kWh and provides $2890.80 savings. Due to weather and cyclic manufacturing, actual runtime is 50%, which reduces savings to $1445.40 annually. Given the company's four year payback return on investment, calculate the NPV with 5% inflation over four years.

Rate at 5%: $\text{Initial PV} = -\$5{,}000$

$$\text{Year 1 PV} = \$1445.40/(1+0.05)^{1} = \$1376.57$$

$$\text{Year 2 PV} = \$1445.40/(1+0.05)^{2} = \$1311.02$$

$$\text{Year 3 PV} = \$1445.40/(1+0.05)^{3} = \$1248.59$$

$$\text{Year 4 PV} = \$1445.40/(1+0.05)^{4} = \$1189.13$$

$$\text{NPV} = -\$5000 + \$1376.57 + \$1311.02 + \$1248.59 + \$1189.13 = \$125.31$$

The net present value is a positive number indicating that the energy project will meet the company's four year payback criterion. It should be noted that, if there are no other negative cashflows associated with the VFD, the energy savings will continue and make NPV more positive as operation continues.

4.7 Required information

Before the engineer can begin to estimate the cost of primary and alternate power-distribution systems, certain information is required:

- A load survey should be prepared. The kVA or kW load, in-rush current, nature of the operation, degree of reliability required, and requirements for future expansion should be considered.
- Availability of utility power should be determined. What is the available distribution voltage, the capacity, and the projected reliability of that source to meet the plant's need? Is a second utility source available to provide added reliability?

4.7.1 Single line, layout/plan

Begin with an accurate, complete single-line diagram and a layout. The layout or plan will show where equipment will be located, the access to these locations for installation (including activities of other trades), maintenance, potential restrictions driven by traffic, environmental, and other concerns. It may be necessary to use good judgment if certain constraints are not evident; however, both the single-line and the layout should be essentially complete and correct.

4.7.2 Initial and prospective loads

Obviously, the initial loads should be known, and usually these loads become defined more and more accurately as the design and estimating project progresses. One basic consideration is: how long will the power system be used, short term or long term? Determining prospective loads frequently requires a high degree of judgment that may require close cooperation with the designer and project manager. Here, the basic purpose of the installation comes into play with questions such as: will production changes affect power distribution? How far into the future need we look? What are the levels of probability for changes in loads?

4.7.3 Availability, sources of power

Utility rates are associated with loading efficiencies and losses, demand charges, scheduled rates. Demand structures can include curtailment, load shedding opportunity costs per the operation/process. Annual inflation per economic and market conditions will vary and contribute to overall project and operating costs. Generation and availability can be from several to multiple sources that have operational characteristics, transmission, distribution, hours of service, and production schedules to balance with consideration of environmental conditions that pose consumption and backup to be accounted for in the design for operation.

4.7.4 Labor: rates, performance, premium time, availability

Direct costs include labor costs where law may require workers employed to be compensated at no less than prevailing wage. Unit labor costs are to include base costs plus all fringes and burdens applicable to each trade. Other items to include are health and welfare, pension, vacation, travel time, etc. Labor rates may be bargained and incremental increases may be mid-year to annual over a several year time period for apprentice, journeyman and lead based on shift, overtime, compensated non-work days per month, guaranteed paid hours per day, potential inefficiencies due to work without time off, and implementation of safe work practices to reduce hazards. Prime contractor's markup on subcontractor's work can be fixed at various percentage of cost plus attributable to additional work, change orders, expedited schedule completions, etc. Prime and contractor's bond and insurance are calculated as percent of total cost of all direct costs and may include other type bonds or incentives at owner's request such as guarantee performance, and payment guarantee, safety bonus award plan, and state/local permits.

5. Factors to consider

After the above information is known, there are several other factors to be considered, which vary in importance depending on the size and type of plant.

Confidentiality: Confidentiality and ethics go together. The estimating engineer cannot, in good conscience, disclose bids or other confidential information without the clear and precise permission of the other party. Further, breaking an implied or stated understanding of confidentiality can bring grave consequences to the engineer and employer.

Commitments and local practices: Be aware of, and allow for, the impact of any commitments made to purchase from a particular vendor, to award the contract to a particular contractor, or any similar action that affects cost. In some situations, it may be prudent to enquire about such details. Local practices can affect costs, so attempt to learn if there are any labor practices, requirements governing restricted access, limitations concerning handling of equipment, or other local practices that affect cost.

Urgency: Know if the project is urgent to the point where the estimate needs to include overtime in the supplier's factory or in the field, expedited delivery of materials, temporary facilities needed until permanent equipment is available; the list of possibilities is large. Work closely with the construction team to learn any details that affect the power system cost estimate.

Schedule: Project duration follow schedules comprised of dates to reflect milestone activity, ranges of activity durations, critical path and float. The construction schedule involves more details for conveying delivery of equipment, installation durations, testing and inspection, startup and commissioning, turnover of documents etc. Conditions that impact daily, weekly, monthly that can delay progress may manifest as a result of environmental conditions of rain, wind, poor air quality, freezing or exceptional high heat temperatures, or other types like labor negotiations, disputes/strikes, road closures, walkouts, turnover, and equipment delivery delays, etc. Where these are more detrimental to execution of the planned work, scope creep can increase completion dates for additional time to be added to the schedule or to be expedited within the original completion date. All these may have impacts that have constant influence on meeting schedule objectives.

Integrating to existing facilities:

a) Utility rate structures may exist that are conditional to the amount of load, and new loads may result in new negotiated rates.

b) Modes of operation which can include maintenance, testing, and tapping into existing equipment requires shutdowns, and possibly loss of production or use.

c) New equipment may contain devices whose servicing and operation are unfamiliar to existing facility operators and maintenance personnel.

d) Safety is the responsibility of the facility owner. Contractors and subcontractors should coordinate their safety practices with those of the owner.

References to consider include IEEE Std 3007.1™ [B8], IEEE Std 3007.2™ [B9], and IEEE Std 3007.3™ [B10].

6. Preparing the estimate

6.1 General

The capital cost of a power system is the sum of the equipment and material costs, cost of installation, commissioning, testing, and start up, plus miscellaneous other costs incurred to provide a complete and ready-to-operate system. Include the entire system when making economic comparisons as each part is economically related to the whole.

The cost estimate will be used by many people. Therefore, the estimate should clearly identify items that are included and the source or basis for estimating figures. Also, closely related items that affect the ultimate cost but are not identified as "not included" in the estimate should be identified so they are not overlooked.

A cost estimate involves the quantitative assessment of typical resource costs required to complete the activity, e.g., project. Costs for developing an estimate are compiled through an iterative process. At the beginning, assumptions may outnumber hard facts and associated figures. This process refines itself from one phase of the project to another, and will improve as specifics are known and included. This will allow the accuracy of an estimate to be improved from a rough order of magnitude to a refined estimate with a much higher level of accuracy while accounting for all the resource costs. Resources may include, but are not limited to, materials, equipment, labor, services, existing facilities integration, plus special categories such as inflation, costs of quality, contingency, etc. Refer to PMBOK Guide 4th edition. [B1]. When developing relative costs, the time to complete the estimate and available information may be limited; therefore, it may be necessary to make assumptions. Assumptions should be clearly documented and included as part of the estimate. Typical items to cover are design engineering, premium time allowance, field engineering, taxes, permits, shipping, foundations, contingencies, unusual scheduling, construction conditions, spare parts, and start-up assistance.

Many estimating programs are available on the market and, some companies have developed their own programs for use in-house. The National Electrical Contractors Association (NECA) provides a variety of estimating programs with related training programs for their members. Estimating programs usually contain a database of current costs for many items and are useful in estimating costs for installation of equipment and for standard items such as conduit and wire, supporting materials, and grounding. However, major items, such as substation transformers, usually are custom-engineered. A quotation from the manufacturer may be desirable for these items.

Recognize that the estimate will include prices that are not fully accurate, labor estimates that are subject to field variations, factors that impact basic assumptions, and many other things. There is no merit in spending an inordinate length of time trying to get the estimate accurate to the last dollar because it cannot be done. Use judgment based on the class of estimate that is required.

6.2 Company practice

Each company has its own method for economic analyses and cost analyses. The estimating engineer should structure the estimate so the costs that occur beyond the fundamental labor and material costs are addressed in the way that is desired by the company. An early discussion with the financial or accounting department can be fruitful. The company may have developed proprietary forms, spreadsheets, processes, and costs or cost models for construction based on cost or resource loaded schedules, unit cost application and activity driven.

Companies can establish and implement estimating standards that follow, for example, the estimate classifications established by AACE International, for levels 5 to 1 (order of magnitude, study, preliminary, definitive and detailed) based on information known and application of a range of percent accuracy from High to Low of –30% to +100%, down to –5% to +15% respectively. Practices of professional cost estimators may establish a format to provide a systematic approach in estimate development. One example of 12 key steps in formulating the estimate for high quality are as follows:

1) Define the purpose of the estimate
2) Develop an estimating plan
3) Identify the project (or program) characteristics
4) Develop the estimating format [e.g., Work Breakdown Structure (WBS)]
5) Define the ground rules and document the assumptions
6) Gather data
7) Compare estimate with an independent cost estimate
8) Analyze the sensitivity
9) Develop the risks and uncertainty analysis
10) Document the estimate
11) Obtain management (stakeholder/owner) approval of the estimate
12) Provide updates to the estimate to reflect actual costs and changes

Determining the estimating structure includes the need to develop a "product-oriented" WBS that reflects the requirements and basis for identifying resources and tasks necessary to accomplish the project's objectives. AACE International[5] and DOE 413.3–21A [B2].

6.3 Third party tools and programs (commercial software)

New technology in hardware and software allow estimating to be conducted more efficiently than in the past. This applies to estimating with off-the-shelf licensed software. These software packages may include annual fees and offer modules with enhanced features and tools. The software may have supplementary forms and spreadsheets. The types of estimating software may include or be selected with common types of estimates such as detailed, unit based, model, project comparison, and parametric. There are software inputs required for interactive quantity inputs and or units, labor and burden rates.

6.4 Project feedback, comparison with estimate, update procedures

Lessons learned can be useful for improvement of future estimates using knowledge of where the estimate was over, under, and missed. This helps with estimates for accuracy and details for future, similar type construction and application of estimating methods for producing appropriate cost ranges and classes of estimates. It is also

[5]AACE International publications are available online at https://web.aacei.org/.

helpful to be involved during construction as well post-construction for awareness of construction methods followed, schedule/equipment delay causes or where expediting could affect the budget that was based on the project estimate. Communication with project/construction management may allow an exchange of installation or construction procedures that results in efficiencies in labor consumption in certain conditions and prove cost effective. Estimators are stakeholders and part of the communication plan. They can contribute by pricing change orders, scope creep and equipment changes to follow budget and maximize return on investment.

6.5 Classes of estimates

6.5.1 General application

The three basic types of estimates are the preliminary estimate, the engineering estimate, and the detailed or final estimate. The three types vary in accuracy as well as in time and effort required for preparation, with each successive estimate containing more detail and requiring more time. It is important to include sufficient money in the engineering budget to cover costs for the estimating activity.

These correspond with the classes defined by the AACE International as Class 4, Class 3, and Class 1, respectively. Refer to AACE 18R for additional information.

6.5.2 Preliminary estimate

The foundation of a sound preliminary estimate is good judgment. One approach is to use the known cost of a similar installation and scale that cost to the size of the system under study, allowing for any differences in conditions associated with the new system, such as location, new technology, new design concepts, unusual labor productivity, and changes in costs of equipment and labor. Typically, the project cost will range from 15% below to 40% above the preliminary estimate.

This level of estimate is typically based from project design deliverables at a 1% to 15% level, for instance an early schematic design, and would be considered a Class 4 estimate usually used for feasibility.

6.5.3 Engineering estimate

A typical engineering estimate requires a one-line diagram, a good understanding of what the final installation will include, layouts, and a comprehensive list of equipment. Prices of major items should be obtained from vendors or from previous purchases, and judicious use should be made of updated data from past jobs, other materials, and installation costs. An example is included at the end of this chapter. Typically, the actual cost will range from 10% below to 20% above the estimate.

Design deliverables would typically be at a 10% to 40% level in order to support a Class 3 estimate and may be use for budget authorization.

6.6 Detailed estimate

In most cases, detailed estimates are done by experienced professional estimators using established procedures. Often firm quotations are obtained from vendors. These estimates include quotations for detailed material requirements that consider bidding and construction specifications taken from completed drawings. This level of accuracy applies for contractors submitting fixed price bids and should apply to engineers who prepare an “engineer’s estimated cost” that will be used in evaluation of bids. Detailed estimates should be ±5% to 10% of final cost.

Design deliverables are complete, and this level of estimate is used for comparison of bids received from prospective vendors and/or contractors.

6.7 Cost categories

Equipment and material costs: Changing markets preclude publishing a list of typical costs for equipment and material in this guide. Up-to-date costs may be obtained from recent purchases or quotations for the specific project under study, manufacturers' and distributors' published prices (include all increases and discounts in the price), and from published estimating guides. The accuracy of the estimate will depend upon major items being priced accurately. Minor items may be covered by an allowance based on judgment or established percentages. Do not miss any line items. If the cost of a line item is not known, say so in the estimate and provide an explanation for the number that is used.

Beyond basic equipment sizing, costs may vary based on the material of construction (e.g., aluminum versus. copper bussing), enclosure requirements and protection/controls complexity, such as metering and relaying requirements.

Installation costs: Since installation costs are significantly impacted by labor productivity and wage rates, refer to previous experiences, to local contractors, and to current estimating guides for information. These costs also vary with time, particularly based on availability of labor in a particular market at a particular moment.

Consider the fact that no task goes as easily as anticipated and, therefore, some contingencies should be added to time estimates. The estimate should include the cost of one or more trips to the warehouse to pick up materials, time to get the tools, coffee breaks, and other overhead considerations, in addition to the actual work. Also included should be an allowance for premium time or overtime and consideration of crew size and, on small jobs, the non-working supervisor. Costs that vary with location, season, and time should be adjusted to reflect anticipated actual costs. Costs vary from country to country and from region to region. Cost of work performed during extremes of cold or hot weather usually varies from that performed during more moderate weather. Cost escalators might be appropriate for work to be done at a future date. Most accounting and estimating departments have established procedures for coping with the time element.

Other costs: Other costs to be considered include a contingency item to cover miscellaneous costs beyond those defined in the estimate. Contingencies adjust for estimating errors, unforeseen complications, and miscellaneous small tasks, but not for omission of significant items nor for changes in scope. Environmental remediation could have latent costs associated with contingency. There are ways to associate the value of risks with mitigation. They can involve tasks or activities, and may differ for equipment, material, and labor. Contingency values are a judgment decision.

An adjustment reflecting inflation modifies costs at the time the estimate is made to anticipate costs at the time expenditures are made. Usually the estimating or accounting department has established procedures for addressing this problem, but the estimating engineer should adjust the estimate for any known factors, such as manufacturers' and distributors' escalation clauses, expediting charges, or extended warranties.

If salvage values for equipment, cable, etc., are known, they should be recognized. Although they may not be credited to a project, they can be important contributors to the overall financial health of the company.

Engineering costs for a project should include engineering studies, preliminary plans, estimates, preparation of construction drawings and specifications, equipment specifications, review of equipment and construction bids, etc. Engineering costs should be assigned whether the work is done by the owner or by consultants.

A complete estimate will also include the costs of:

- Construction supervision
- Construction mobilization and demobilization
- Field engineering

— Services of manufacturers' representatives
— Testing, training, commissioning
— Other requirements that may apply

If these are not made part of the estimate, make clear what is included and what is omitted.

Annex A
(informative)
Example

A.1 General

The following example shows one technique for developing an engineering cost estimate. The reader should not use the dollar figures because undoubtedly, they will be out-of-date and probably not directly applicable to the specific project.

Note that costs are segregated to show major items purchased by the owner, equipment, and material provided by the contractor, and labor provided by the contractor.

The labor portion of the estimate is developed on a man-hour basis and then multiplied by the labor rate to obtain dollar amounts. This technique facilitates revising the estimate as labor rates change. Also, the man-hour information provides a ready means to check the estimate by comparing time actually spent on the job with time as estimated. For reference on subsequent jobs, the man-hour estimate without the effect of labor rates will prove more useful than dollar amounts.

A.2 Design data

Typical power distribution system projects have been depicted in Figure A.1, Figure A.2, and Figure A.3, and enhanced with a site plan in Figure A.4. Figure A.5 illustrates a typical blank estimate sheet. Table A.2 through Table A.5 show the actual estimate for the system described.

A.3 Supporting data

A file of quotations and other information that substantiates the cost data should be maintained (not included in the example in this subclause, however). An allowance in the contractor's material for the overhead expenses and profit should be included.

Direct labor costs may be used for each line item with overhead, profit, etc., added in the summary. Alternatively, total costs and profit can be added in the cost per man-hour. In this example, all costs are included in the cost per man-hour.

Cost/man-hour for estimate: For the example in Table A.1, assume one superintendent with three crews, each with four working journeymen and one working foreman. The total crew is 16, with 15 electricians working with the tools. Assume the average work week is 40 h at straight time and 4 h at premium time.

Table A.1—Example of a schedule for estimating man-hour cost

Payroll cost/week:							
Journeyman	(12)	×	(40)	@	($____/hr)	=	$
	(12)	×	(4)	@	($____/hr)	=	$
Foreman	(3)	×	(40)	@	($____/hr)	=	$
	(3)	×	(40)	@	($____/hr)	=	$
Superintendent			(40)	@	($____/hr)	=	$
			(4)	@	($____/hr)	=	$___________
Subtotal #1, payroll. Cost/wk							$
Add to the payroll cost:							
Direct labor charges _______%						=	$
Indirect labor charges ______%						=	$___________
Subtotal #2, payroll, direct and indirect						=	$
Add to Subtotal #2:							
Contractor's profit ________%						=	$___________
Subtotal #3, costs and profit						=	$
Divide subtotal #3 by 15 to obtain the average cost per man-hour for this estimate. For purposes of this example, the average cost is assumed to be $120.00/man-hour.							

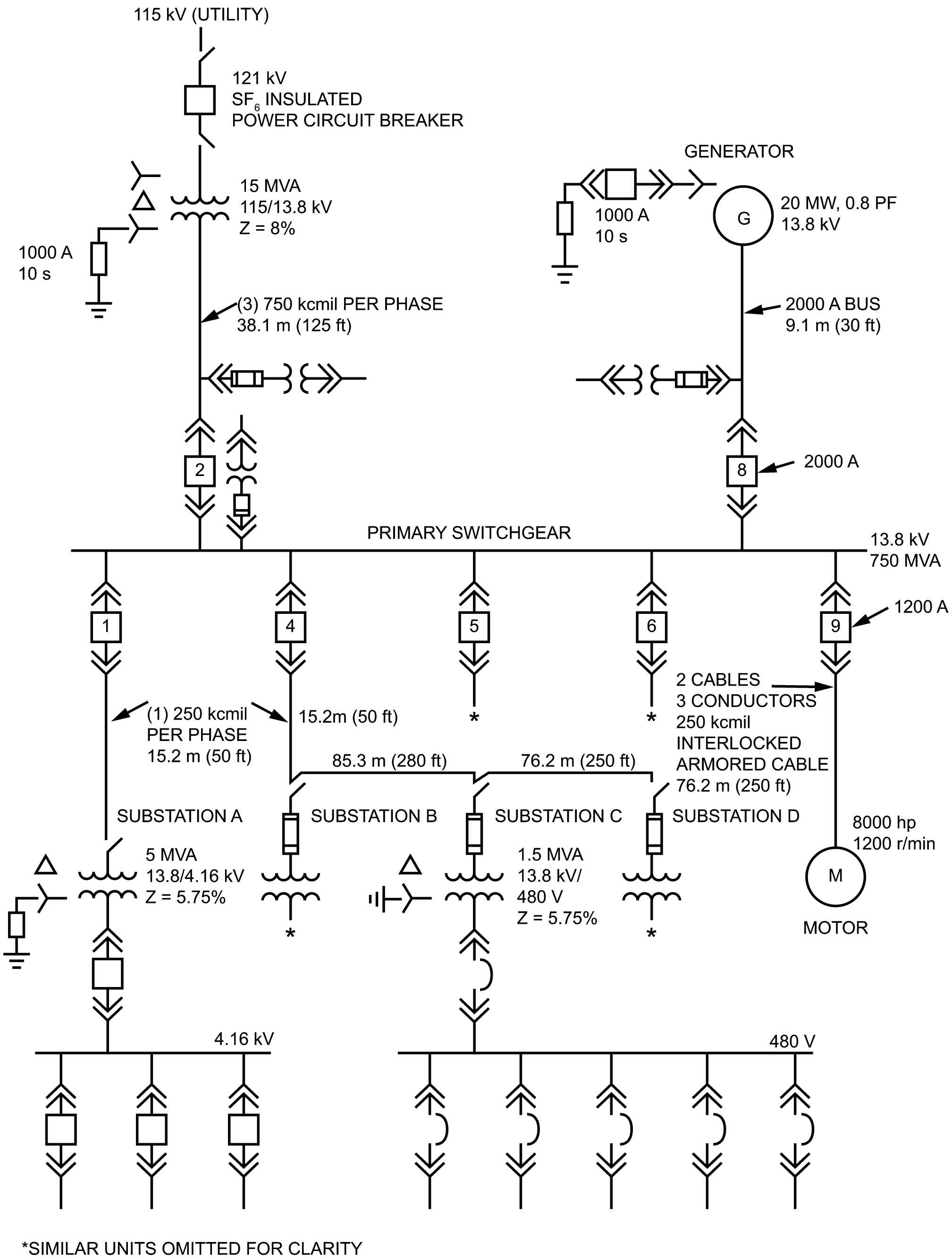

Figure A.1—Single line diagram

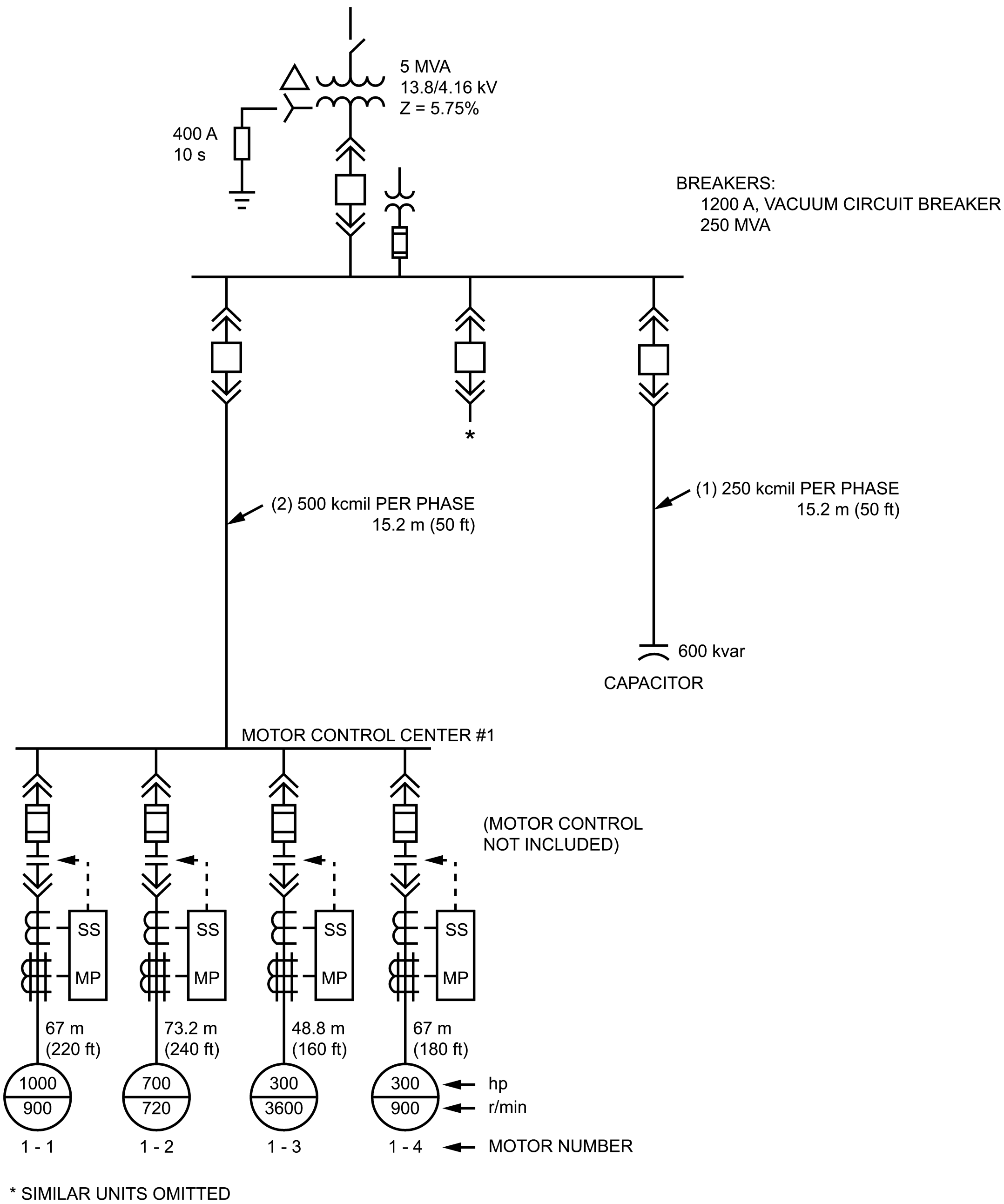

Figure A.2—5 MVA, 4.16 kV substation and motor control center

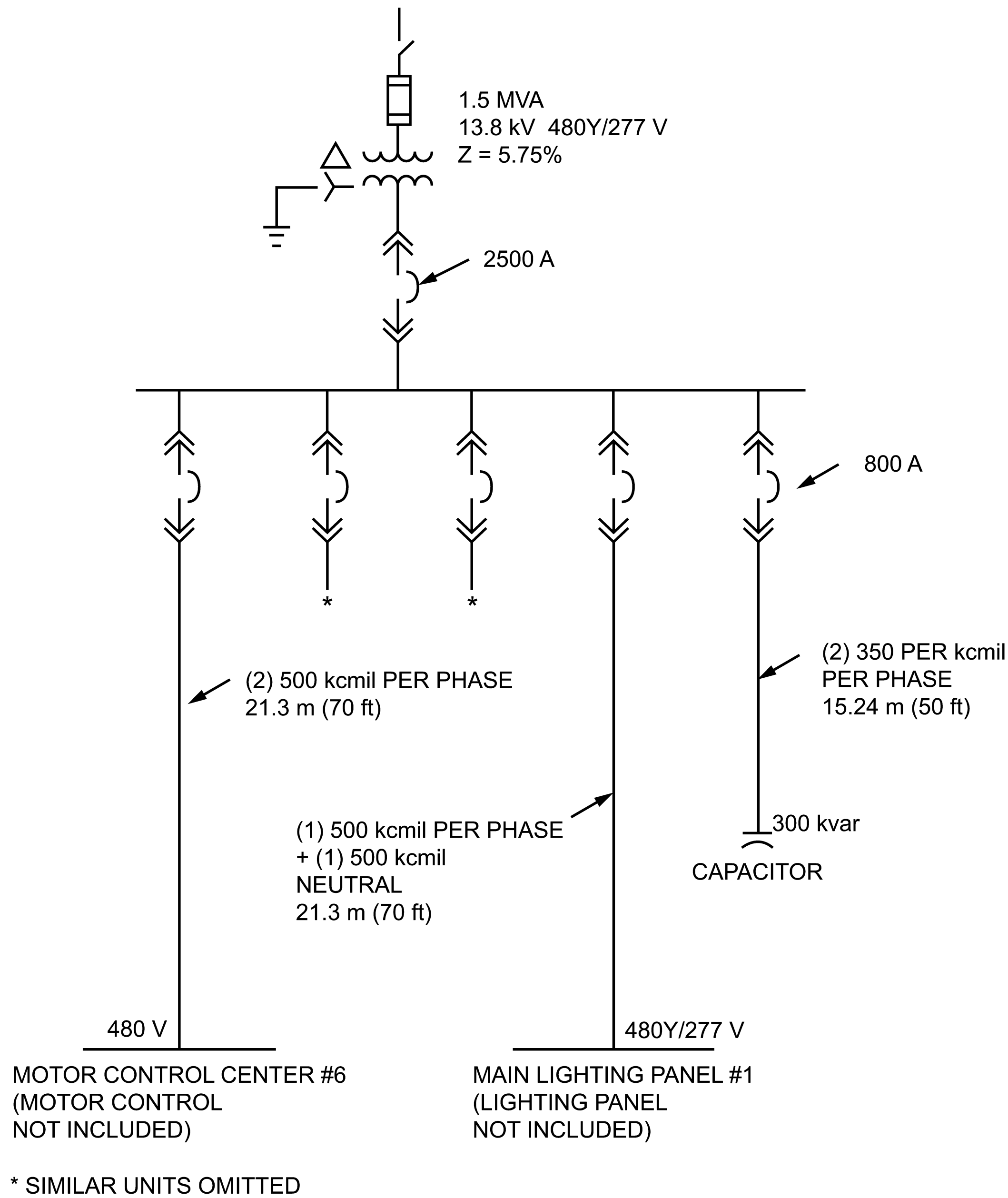

Figure A.3—Substation C: 1.5 MVA, 480Y/277 V

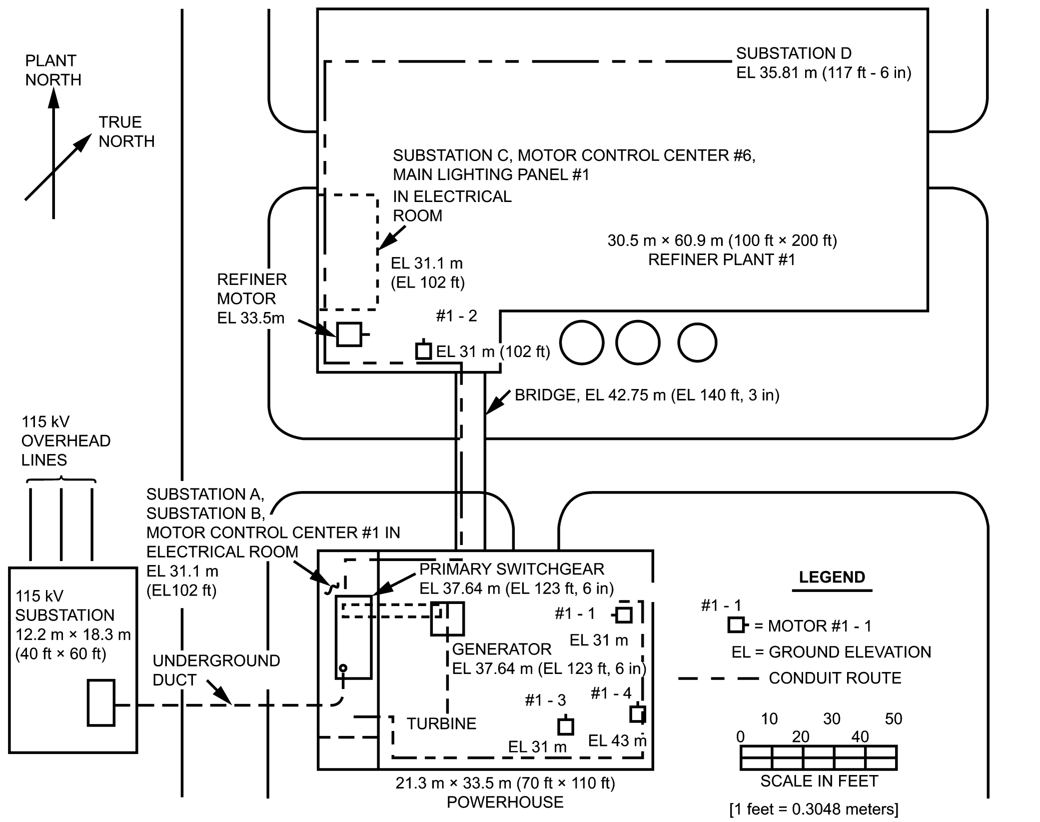

Figure A.4—Site plan

PROJECT: Industrial Plant Power System
LOCATION: Centerville USA

ESTIMATE SUMMARY SHEET

SHEET X OF X

ITEM No.		DESCRIPTION	QUANTITY	$(XX) per UNIT	$(XX) MATERIAL by Owner	$(XX) MATERIAL CONTRACTOR	HOURS/UNIT	LABOR HOURS	$ @ $(XX)/HR	TOTAL $

(NOT INCLUDED IN ESTIMATE: FREIGHT, SPARES, TRANING, CONTINGENCY, ESCALATION, SALES TAX, PERMITS AND FEES, BOND, FOUNDANTIONS, LIGHTING, COMMISSIONING)

Figure A.5—Cost estimate calculation sheet

Table A.2—Sample cost estimation calculation: Summary

Description	Material cost by owner ($)		Material cost by contractor ($)		Labor cost ($)r		Total cost ($)
	By item	Total	By item	Total	By item	Total	
Primary power 13.8 kV							
Outdoor substation	852,976		12,416		139,800		1,005,192
Incoming feeder	44,856		20,132		77,520		142,508
Primary switchgear	569,600		13,617		62,400		645,617
Generator—included in mechanical							
Generator bus	25,810		2,047		36,000		63,857
Feeders	37,594		17,781		104,280		159,655
Grounding			11,214		26,400		37,614
Subtotal primary power		1,530,836		77,206		1,311,792	2,054,442
Substation A, 4.16 kV							
Unit substation	319,510		8,811		37,200		348,611
Feeders			9,644		21,264		30,908
Capacitor			10,680		3,000		13,680
Subtotal substation A		319,510		29,135		61,464	393,199
Substation C, 480 V							
Unit substation	167,320		4,005		23,640		194,965
Feeders			14,158		31,008		45,166
Capacitor			8,010		2,400		10,410
Subtotal substation C		167,320		26,173		57,048	250,541
Power system total		2,352,306		184,861		1,544,400	3,199,264
Values to use		2,353,000		185,000		1,545,000	3,200,000
NOTE—Not included in estimate: freight, spares, training, contingency, escalation, sales tax, permits and fees, bond, foundations, lighting, commissioning.							

Table A.3—Sample cost estimate calculation sheet: Primary power

Item no.	Description	Qty	Per unit cost ($)	Material cost by owner ($)	Material cost by contractor ($)	Labor hours per unit	Labor hours	Labor cost @ $120/hr ($)	Total cost ($)
1	Incoming line structure	1		240,300			500	60,000	300,300
2	SF_6 circuit breaker 121 kV	1		89,000			100	12,000	101,000
3	Transformer, 15 MVA, 115-13.8 kV (see quote)	1		514,420					514,420
	Foundation included in structural estimate								
	Handling, rigging, installation				2,492		400	48,000	50,492
	Primary connections				4,628		100	12,000	16,628
	Testing (subcontract quote + 15%				2,359				2,359
4	Grounding resistor, 100 A, with CT	1		9,256					9,256
	Supporting structure				2,492		15	1,800	4,292
	Install, connect, test				445		50	6,000	6,445
	Subtotal outdoor substation			852,976	12,416			139,800	1,005,192
5	15 kV incoming feeder								
	Trench and backfill 457 mm x 1067 mm (18 in x 42 in);	65	97.9		6,364	0.15	10	1,170	7,534
	7.6 cubic meter (10 cubic yd) fill								
	Concrete-encased duct; (3) = 4 in; (1) = 2 in	65	115.7		7,521	2	130	15,600	23,121
	Conduit risers 4 in aluminum, including Fittings, hangers	210	21.36		4,486	0.6	126	15,120	19,606
	Cable, 1/C 750 kcmil, 15 kV EPR	1575	28.48	44,856		0.15	236	28,350	73,206
	Terminations	18	97.9		1,762	8	144	17,280	19,042
	Subtotal incoming feeder			44,856	20,132			77,520	142,508
6	Primary switchgear								
	A. Indoor metalclad, 15 kV, 750 MVA, 910 including breakers and aux, (4) feeder breakers, (1) motor starter breaker (see switchgear quote)			364,900					364,900
	B. Add for generator, breaker, and auxiliary neutral, breaker, relaying, sync, battery (see generator quote)			204,700					204,700
	C. Handling, rigging				2,047		100	12,000	14,047
	D. Align, connect, checkout				1,335		420	50,400	51,735
	E. Testing (subcontract quote + 15%)				10,235				10,235
	Subtotal primary switchgear					569,600	13,617	62,400	645,617

Table A.3—Sample cost estimate calculation sheet: Primary power (continued)

Item no.	Description	Qty	Per unit cost ($)	Material cost by owner ($)	Material cost by contractor ($)	Labor hours per unit	Labor hours	Labor cost @ $120/hr ($)	Total cost ($)
7	Generator and auxiliaries, except for item 6b included in turbine-generator estimate; see mechanical estimate, including erection			89,000			100	12,000	101,000
8	Generator bus; 2000 A, 15 kV	Lot		25,810	2,047		300	36,000	63,857
	15 kV feeders								
9	Substation feeders from breakers #1, 4 (#5, 6 not included) 3 in aluminum conduit fittings, hangers Cable CC 250 kcmil, 15 kV, EPR [204 m (670 ft) run] Terminations	630 2010 24	16.02 8.9	 17,889	10,093 960	0.5 0.8 6	315 161 144	37,800 19,296 17,280	47,893 37,185 18,240
10	Motor feeder, 3/C 250 kcmil, 15 kV interlocked armor Supports, bracket, [1524 mm (5 ft) centers] Terminations	540 50 4	36.49 74.76 213.6	19,705	 3,738 854	0.28 1 12	151 50 48	18,144 6,000 5,760	37,849 9,738 6,614
11	Hi-pot test, including incoming and generator bus				2,136		0	—	2,136
	Subtotal feeders			37,594	17,781			104,280	159,655
12	Grounding (includes ground loop for two buildings connections to all 15 kV and 5 kV class equipment: 4/0 AWG bare copper Connectors, rods	2000	3.827		7,654 3,560	0.06	120 100	14,400 12,000	22,054 15,560
	Subtotal grounding			-	11,214			26,400	37,614

Table A.4—Sample cost estimate calculation sheet: Substation A (Figure A.2)

Item no.	Description	Qty	Per unit cost ($)	Material cost by owner ($)	Material cost by contractor ($)	Labor hours per unit	Labor hours	Labor cost @ $120/hr ($)	Total cost ($)
13	A Unit substation—Primary switch	1		302,600					302,600
	Transformer 5 MVA, 13.8 - 4.16 kV:								
	Switchgear section with (4) 2000 A vacuum circuit breakers,								
	Metering, relaying, total cost (see quotes)								
	B Handling, rigging				979		80	9,600	10,579
	C Align, connect, checkout				979		180	21,600	22,579
	D Testing (subcontract + 15%)				2,759				2,759
	E Foundation and room in structural estimate,								
	Lighting in building estimate								
		1		16,910				—	—
14	Grounding resistor 400 A, with CT				3,560		15	1,800	5,360
	Supporting structure				534		35	4,200	4,734
	Install, connect test								
	Subtotal indoor substation			319,510	8,811			37,200	348,611
	5 kV feeders (feeder #2 not included)								
15	3 in aluminum conduit, fittings, hangers	100	16.198		1,620	0.5	50	6,000	7,620
	Cable, 1/C, 500 kcmil, 5 kV, EPR	330	12.104		3,994	0.11	36.3	4,356	8,350
	2-1/2 in aluminum conduit, fittings, hangers	50	14.774		739	0.45	22.5	2,700	3,439
	Cable, 1/C, 250 kcmil, 5 kV, EPR	180	8.544		1,538	0.08	14.4	1,728	3,266
	Terminations	18	64.08		1,153	3	54	6,480	7,633
16	Testing (subcontract)				600		0	—	600
	Subtotal feeders				9,644			21,264	30,908
17	Capacitors, 4.16 kV, 600 kVAR, including installation				10,680		25	3,000	13,680

Table A.5—Sample cost estimate calculation sheet: Substation C (Figure A.3)

Item no.	Description	Qty	Per unit cost ($)	Material cost by owner ($)	Material cost by contractor ($)	Labor hours per unit	Labor hours	Labor cost @ $120/hr ($)	Total cost ($)
	Indoor substation								
18	A Unit substation—fused primary switch Transformer 1.5 MVA, 13.8-4.16 kV, Switchgear section with (4) 2500 A main, (4) 1200 A feeder breakers, metering, (use actual cost from project 80-107 + 12.5%)	1		167,320					167,320
	B Handling, rigging				979		77	9,240	10,219
	C Align, connect, checkout				979		120	14,400	15,379
	D Testing				2,047				2,047
	E Foundation and room in structural estimate: Lighting in building estimate								
	Subtotal substation			167,320	4,005			23,640	194,965
	480 V feeders								
19	2-1/2 in alum conduit, fittings, hangers	100	14.774		1,477	0.45	45	5,400	6,877
	3 in alum conduit, fittings, hangers	140	16.198		2,268	0.5	70	8,400	10,668
	4 in alum conduit, fittings, hangers	70	19.58		1,371	0.62	43	5,208	6,579
	1/C, 250 kcmil, XHHW	80	4.094		328	0.08	6	768	1,096
	1/C, 350 kcmil, XHHW	360	6.052		2,179	0.08	29	3,456	5,635
	1/C, 500 kcmil, XHHW	720	9.078		6,536	0.09	65	7,776	14,312
	Subtotal feeders				14,158			31,008	45,166
20	Capacitors, 480 V, 300 Kvar, including installation				8,010		20	2,400	10,410

Annex B

(informative)

Selected sources for estimating information

This is an abbreviated list of references for cost-estimating information. Omission of other current sources is not meant in any way to be judgmental. Inclusion on this list implies no endorsement by IEEE. The reader is urged to consider all available references.

ConEst
592 Harvey Road
Manchester NH 03103 USA

NECA Manual of Labor Units, National Electrical Contractors Association, Inc.
Three Bethesda Metro Center, Suite 1100
Bethesda, MD 20814

Mechanical and Electrical Cost Data
R. S. Means Company, Inc.
1099 Hingham St, Suite 201
Rockland, MA 02370

McCormick Systems, Inc.
149 West Boston Street
Chandler, AZ 85225

NOTE—NECA information is proprietary. Nonmembers of NECA may contact the national office (address above) or the local NECA office for further information.

Annex C

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] *A Guide to the Project Management Body of Knowledge: PMBOK Guide*, Project Management Institute, 2004.

[B2] DOE G 413.3–21A, Cost Estimating Guide, 2018.

[B3] Downes, J. and J. Goodman, Dictionary of Finance and Investment Terms, Barron's Educational Series Inc., 2014.

[B4] IEEE Policies, Section 7—Professional Activities (Part A—IEEE Policies), 7.8 IEEE Code of Ethics.

[B5] IEEE Std 493™, IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems, (*IEEE Gold Book*™).[6,7]

[B6] IEEE Std 3006.5™, IEEE Recommended Practice for the Use of Probability Methods for Conducting a Reliability Analysis of Industrial and Commercial Power Systems.

[B7] IEEE Std 3006.7™, IEEE Recommended Practice for Determining the Reliability of 7x24 Continuous Power Systems in Industrial and Commercial Facilities.

[B8] IEEE Std 3007.1™, IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems.

[B9] IEEE Std 3007.2™, IEEE Recommended Practice for the Maintenance of Industrial and Commercial Power Systems.

[B10] IEEE Std 3007.3™, IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems.

[B11] Khan, M. Y. and P. K. Kain, Theory & Problems in Financial Management, Second Edition. Tata: The McGraw Hill Companies, New Delhi, 1993. ISBN 978-0-07-463683–1.

[B12] Kumamoto, H. and E. Henley, Probabilistic Risk Assessment and Management for Engineers and Scientists, 2nd Ed. New York: Wiley-IEEE Press, 2000, http://dx.doi.org/10.1109/9780470546277.

[B13] NETA ATS, Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

[B14] NETA MTS, Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems.

[6]The IEEE standards or products referred to in Annex C are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

[7]IEEE publications are available from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).

[B15] NFPA 70E, Standard for Electrical Safety in the Workplace.[8]

[B16] NFPA 70, National Electrical Code.

[B17] NSPE #1102, Code of Ethics for Engineers.

[B18] U.S. Department of Labor, Davis Bacon Act, Title 29 CFR parts 1, 3, 5, 6, 7, United States Code.

[8]NFPA publications are published by the National Fire Protection Association (http://www.nfpa.org/).

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